



ON Semiconductor®

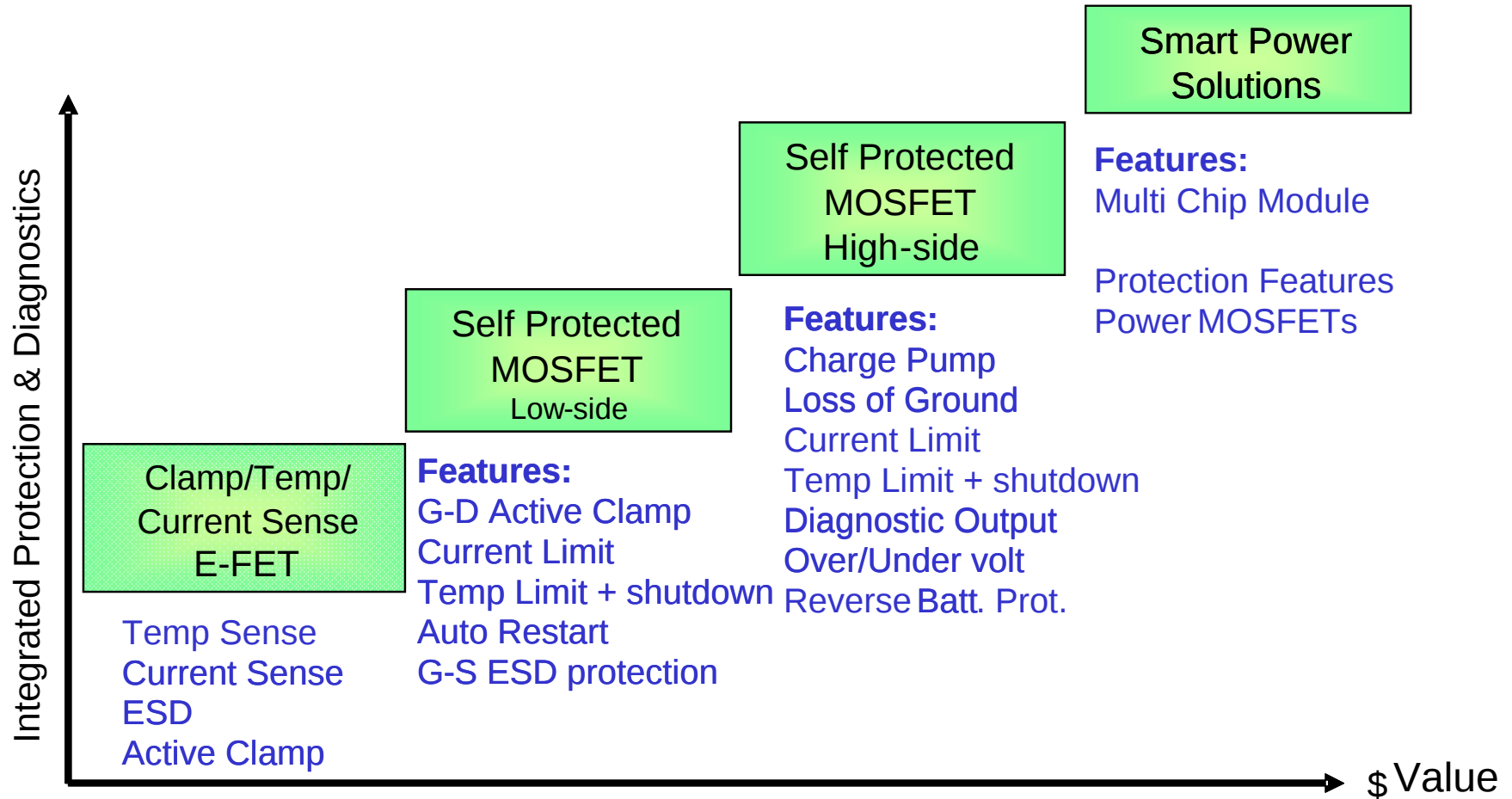
Smart FET Protection Features

Agenda

- Current Limit
- Over Temperature Protection
- Over Voltage Protection
- ESD Protection
- Diagnostic Output
- High and Low Side Portfolio and Applications

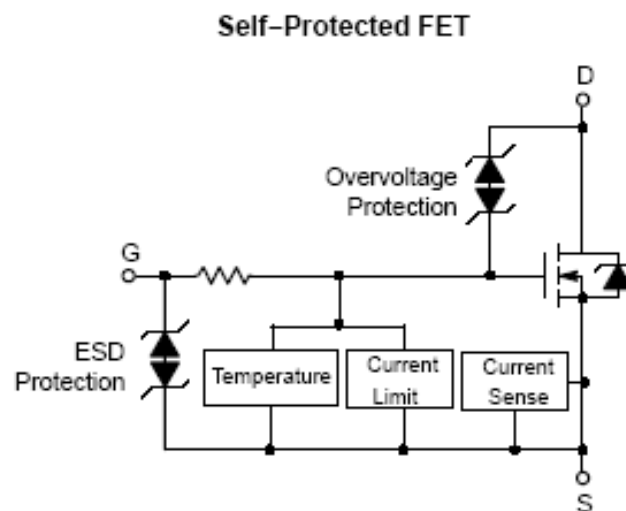


SmartFET Capability



SmartFET enables integration of analog circuit elements in Power MOSFET devices for cost effective solutions

Smart FET Protection Features



- ON Semiconductor's Smart FET's Feature 4 Main Protection Functions
 - Current Limit Protection
 - Over Temperature Protection
 - Overvoltage Protection
 - ESD Protection
- ON Semiconductor's High Side NCV8460 Adds Diagnostic Features
 - Open Load Detection

Current Limit Protection

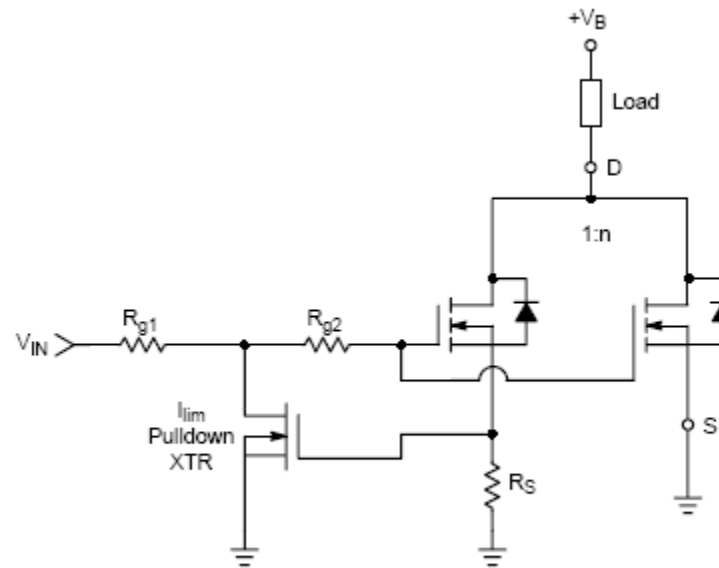


Figure 5. Simplified Current Limit Circuit

- Current from the Drain is mirrored into a smaller device anywhere from $1/200^{\text{th}}$ to $1/1000^{\text{th}}$ the size of the main power device

Current Limit Protection

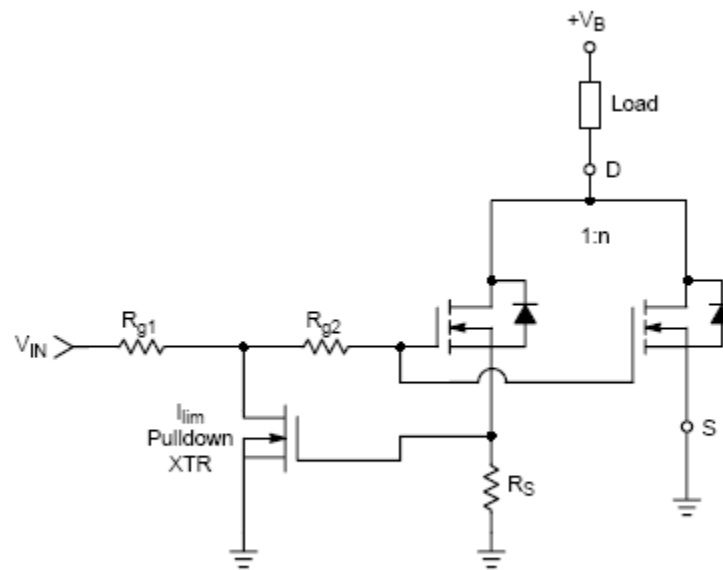
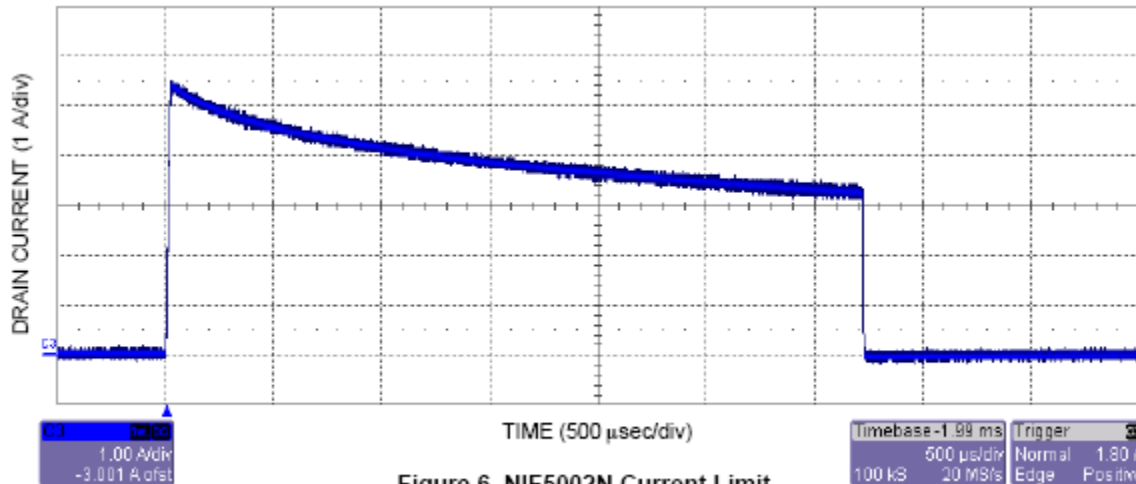


Figure 5. Simplified Current Limit Circuit

- The current through the smaller device develops a voltage across R_S
- As V_{RS} increases, a pulldown FET turns on, and pulls down on the voltage of the main power FET, which reduces output current

Current Limit Protection



- The current limit will vary with temperature
- As can be seen above, as the device heats up, current limit decreases

Over Temperature Protection

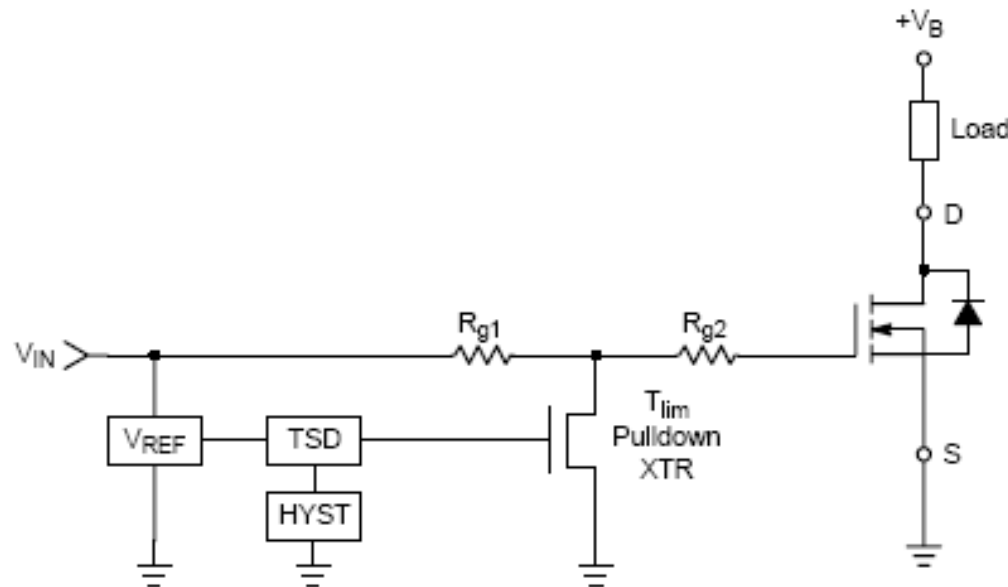
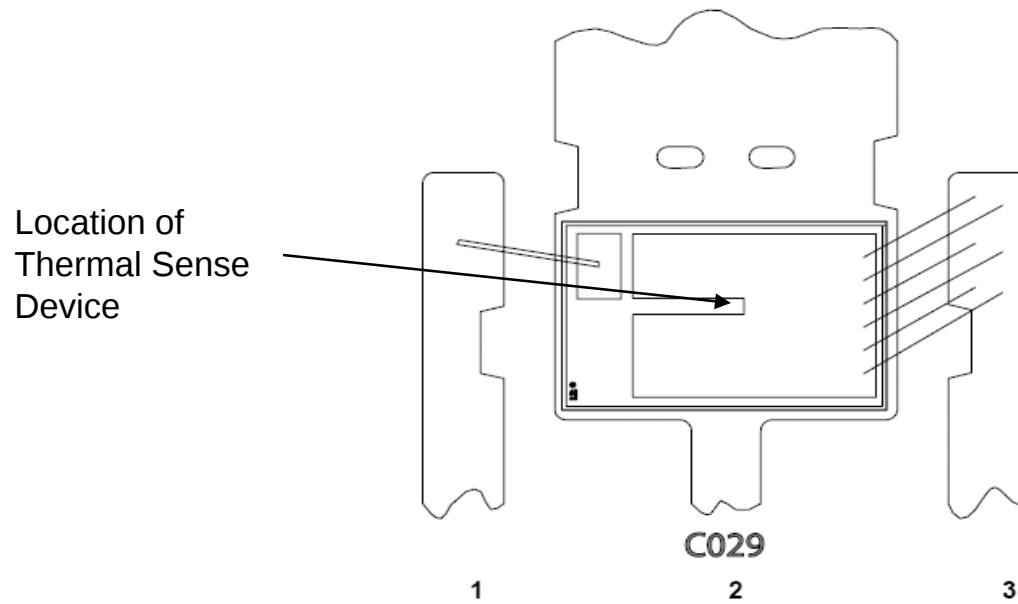


Figure 8. Simplified Temperature Limit Shutdown Circuit

- On Semiconductor's Smart FET's include Over Temperature Protection, which shuts down the device when the temperature exceeds a predetermined threshold
- If the TSD structure indicates a high temperature, the T_{LIM} Pulldown device pulls the voltage down on the main power device.

Over Temperature Protection



- A reference voltage is compared to the TSD structure, a diode structure, located in the die's 'hot spot'

Over Temperature Protection

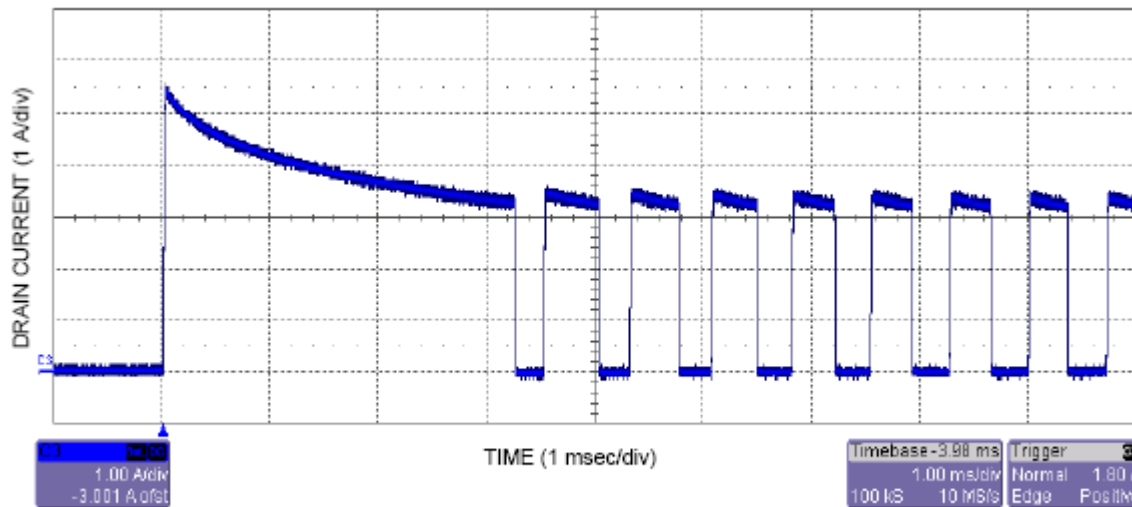


Figure 9. NIF5002N Current Limit Expanded, Showing Thermal Cycling

- Once the TSD structure indicates the temperature has dropped, the pulldown device turns off, allowing the main power device to turn back on
- The typical hysteresis is 15 C

Over Voltage Protection

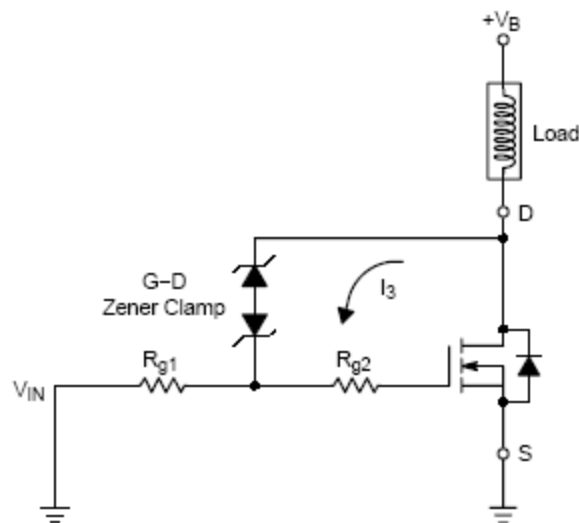
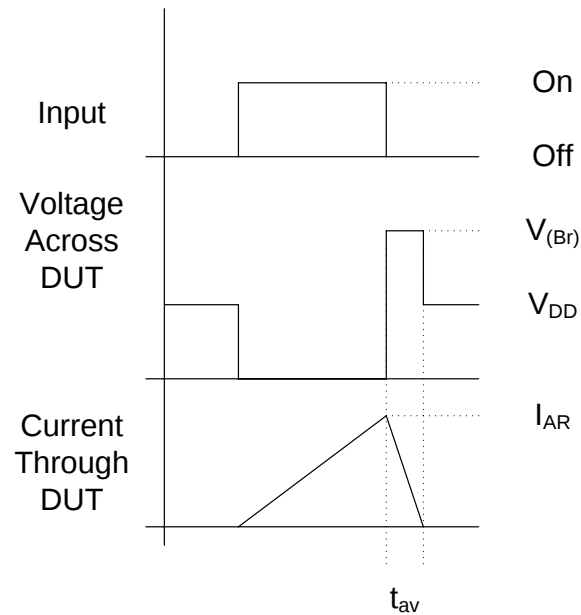


Figure 12. Simplified Active Clamp Circuit

- A Gate to Drain Zener Clamp provides overvoltage protection
- The clamp allows the Gate to turn on, spreading the energy more evenly across the active area

Over Voltage Protection



- Voltage across DUT is clamped during an inductive flyback event
- When the input is turned off, the voltage across DUT increases until it reaches the clamp level, typically around 45 V

ESD Protection

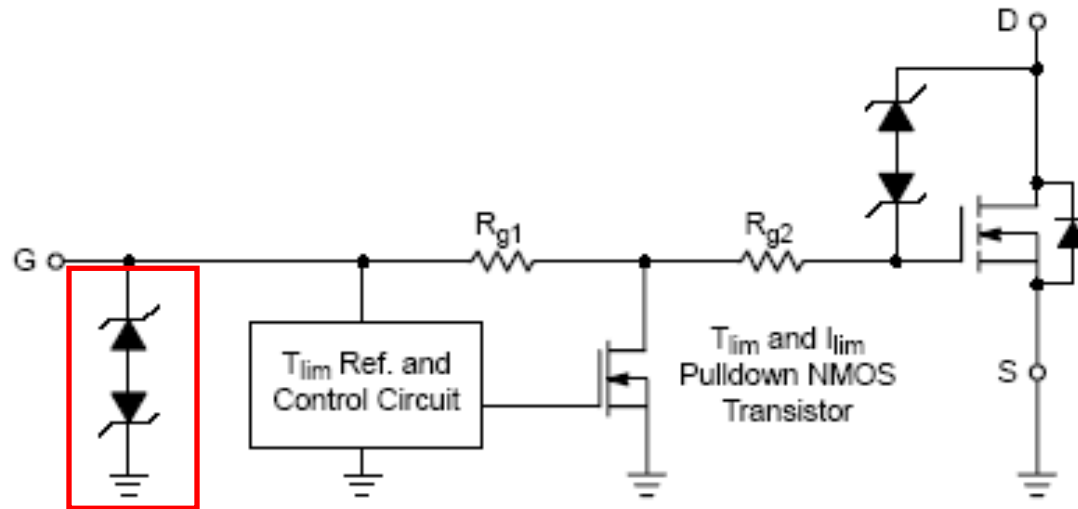
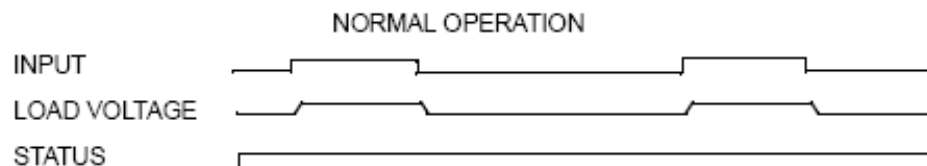


Figure 3. Simplified Input Circuit

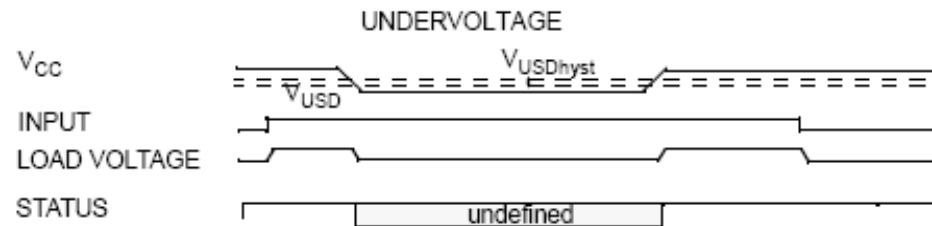
- Back to Back diodes on the Gate pin clamp the voltage to 13 V
- This combined with the internal series resistance allow a minimum of 4000 V Human Body Model and 400 V Machine Model ESD capability
- The Source and Drain are inherently protected through the device structure itself

Diagnostics

- The NCV8460 offers diagnostic features and a status pin
 - Normal Operation- Status Pin High



- Undervoltage-
 - Status Pin Undefined
 - Output Turns Off

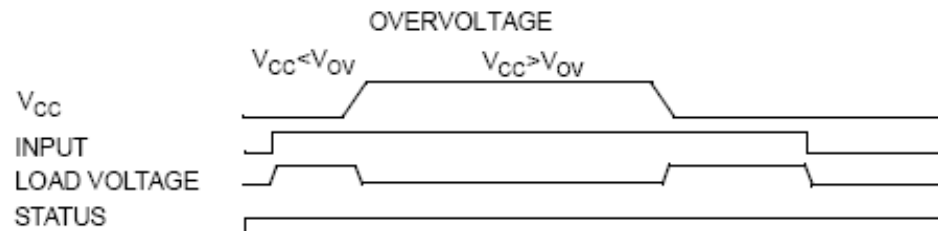


Diagnostics

- The NCV8460 offers diagnostic features and a status pin

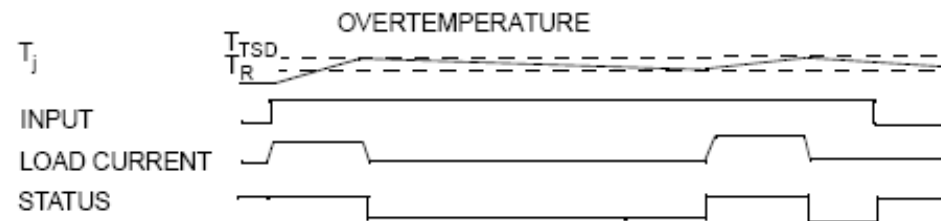
- Overvoltage

- Status Pin Stays High
- Output Shuts Off



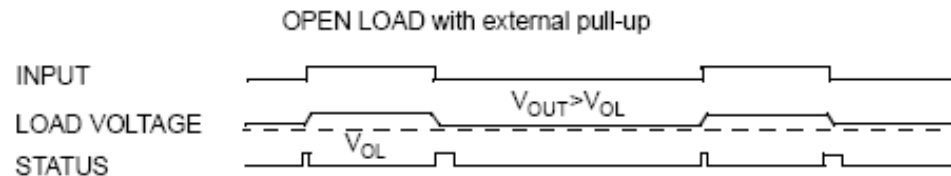
- Over Temperature

- Status Pin Goes Low
- Output Turns Off

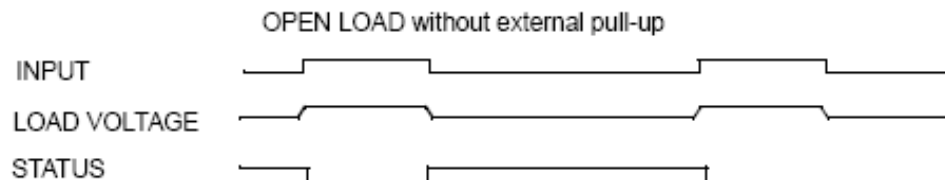


Diagnostics

- The NCV8460 offers diagnostic features and a status pin
 - Open Load With External Pull Up
 - Input High- Status Pin Goes Low When Open Load Detected
 - Input Low- Status Pin Goes Low When Open Load Detected



- Open Load Without External Pull Up
 - Input High- Status Pin Goes Low When Open Load Detected
 - Input Low- Status Pin Stays High Regardless of Load Condition



Potential Failure Modes and Mitigation Strategies

Potential Failure Mode	Mitigation
Insufficient gate drive during fault condition	-Increase current source/sink capability of gate drive circuit -Increase gate drive voltage
Excessive dV/dt at drain	-Increase series gate resistance -Filter or snubber circuits to eliminate fast edge transients -Reduce supply voltage
Excessive die temperature during SCIS operation	-Reduce load inductance -Reduce circuit parasitic inductance -Use lower clamp voltage device -Use device with proper energy rating -Decrease device duty cycle or frequency or both -Use parallel devices
Excessive die temperature during load dump or other transient event	-Increase load resistance -Improve transient thermal response via better thermal pathway or larger silicon active area -Use parallel devices



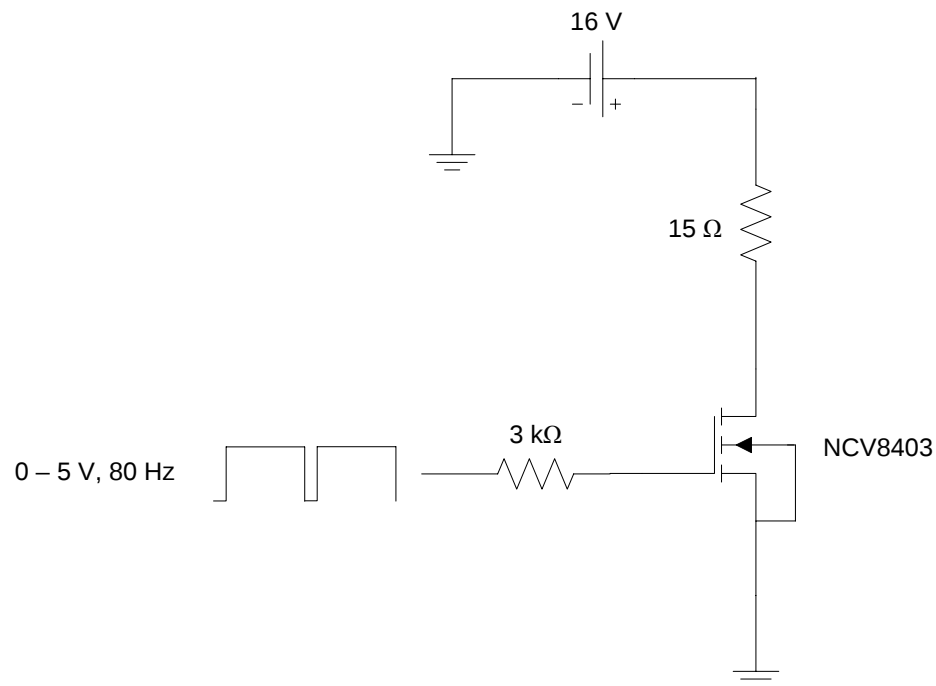
ON Semiconductor Low Side Portfolio

- NCV8401
 - 33 A Current Limit, 23 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8402 and NCV8402 Dual
 - 2 A Current Limit, 165 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8403
 - 15 A Current Limit, 53 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8405
 - 6 A Current Limit, 90 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8440
 - 95 mOhm RDSOn
 - 52 V Clamp Only, No TSD, or Current Limit
- NIMD6001 (Dual)
 - 110 mOhm RDSOn
 - No Clamp, TSD or Current Limit
 - Over Voltage Diagnostic Signal



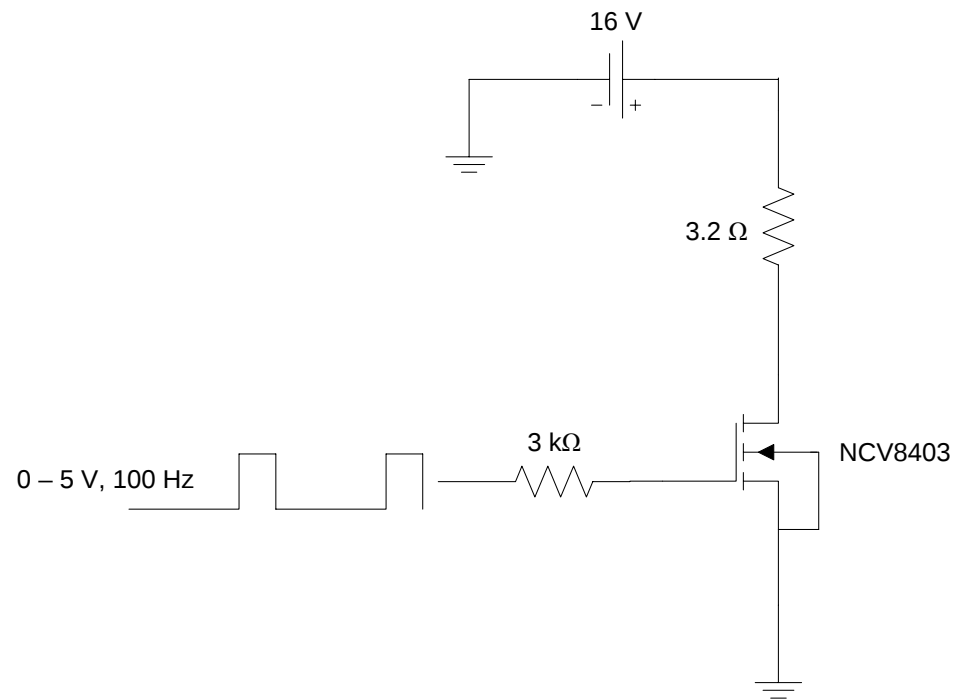
Low Side Applications

- Split Cooling Valve Sensor- NCV8403
 - The Drain is used to drive a heater resistor to control a thermostat
 - As the resistive load heats up, the thermostat heats up causing it to be over-ridden
 - A 3 k Ω gate resistor is used to slew the switching speed.



Low Side Applications

- Lambda Sensor- NCV8403
 - A lambda sensor is a resistive load
 - The sensor measures the oxygen content in the exhaust gas
 - A 3 k Ω gate resistor is used to slew the switching speed



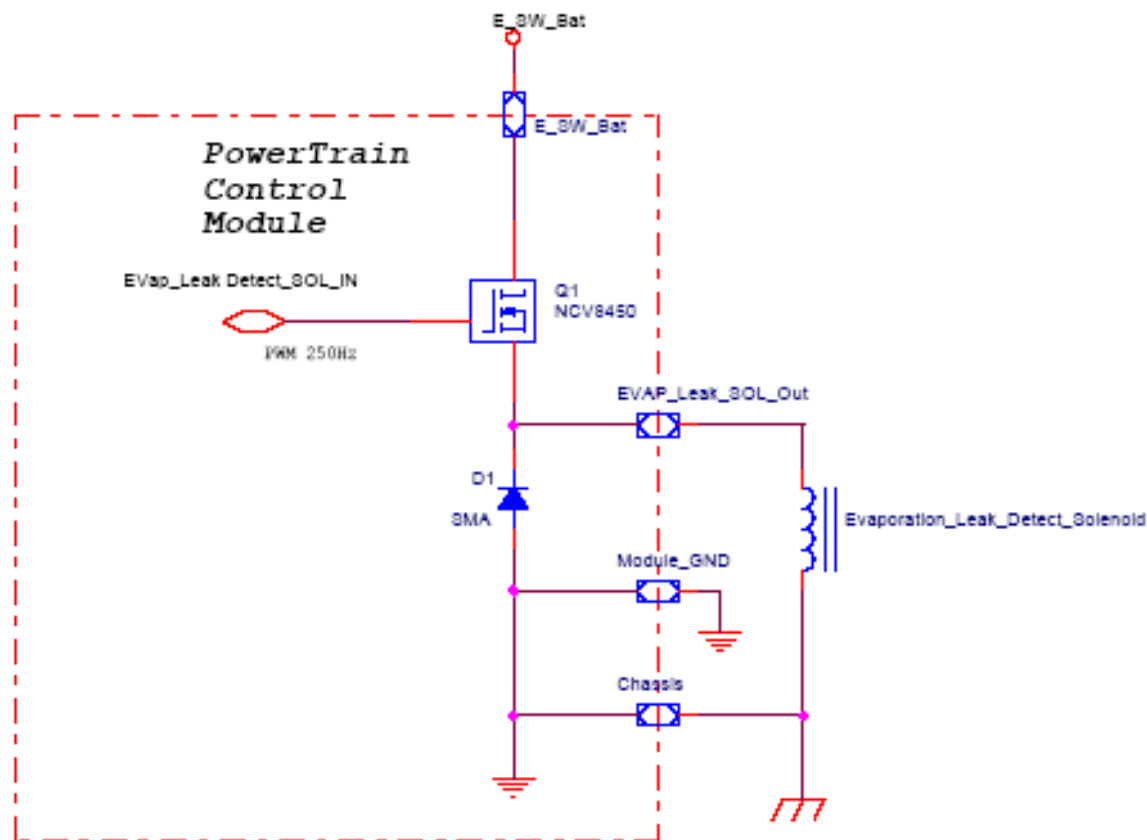
ON Semiconductor High Side Portfolio

- NCV8450
 - Released
 - 1 A Current Limit, 1 Ohm RDSOn
 - No Diagnostic Features
 - Cross to BTS4140
 - Voltage Clamped to 45 V, 175 C TSD
- NCV8460
 - Currently in Design
 - Diagnostic Features
 - On State Open Load Detection
 - Off State Open Load Detection
 - Diagnostic Output
 - Under Voltage and Over Voltage Shutdown
 - 9 A Current Limit, 60 mOhm RDSOn
 - Cross to VN750
 - Voltage Clamped to 42 V, 175 C TSD



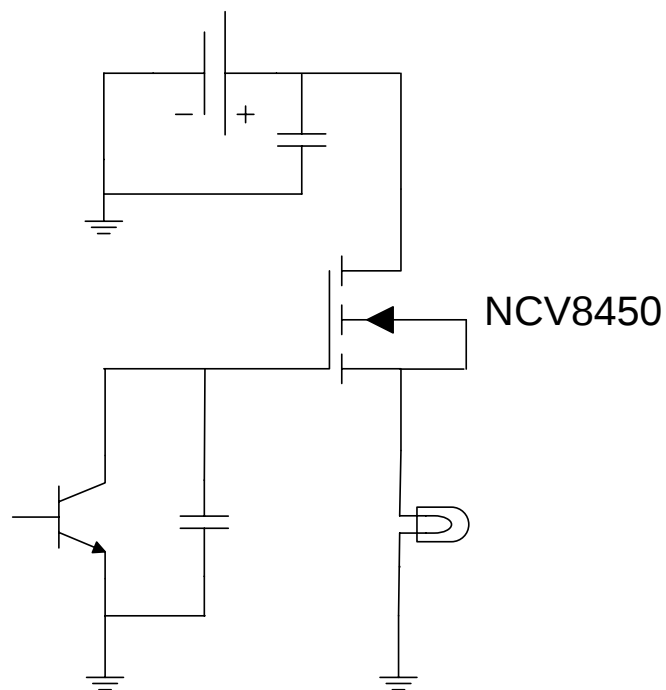
High Side Applications

- Power Train Application- NCV8450
 - Evaporation Leak Detection Solenoid



High Side Applications

- Brake Light Application- NCV8450
 - Open Collector Hall Sensor Used to Drive NCV8450



Conclusion

- ON Semiconductor's SmartFET offers 4 main protection functions
 - Current Limit
 - Over Temperature Protection
 - Over Voltage Protection
 - ESD Protection
- ON Semiconductors' new NCV8460 adds a Diagnostic Output Feature



For More Information

- View the extensive portfolio of power management products from ON Semiconductor at www.onsemi.com
- View reference designs, design notes, and other material supporting automotive applications at www.onsemi.com/automotive

